Design and characterization of an Optical Proximity Correction (OPC) mask.

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Abstract- A normal binary chrome mask is designed with optical proximity correction features to test their effect on the lithographic image formed. A significant image improvement is seen due to the addition of the OPC features.

I. Introduction

Photolithography is one of the most important processes in Integrated Circuit (IC) manufacturing driving the scaling of CMOS technology. The continuing drive for higher performance integrated circuits at a lower cost requires continued reductions in the size of features that can be resolved by the lithographic process. When the features to be resolved are of a size comparable to the exposure wavelength, optical proximity effects (OPE) severely limit the process window. Off Axis Illumination (OAI) and PSM's, while improving the stepper depth of focus, do not correct for optical proximity effects.

Optical Proximity Effects (OPE) are caused by optical diffraction patterns of adjacent features interacting with one another to produce pattern dependent CD variations leading to edge degradation's, line end rounding and shortening, reduced pattern fidelity at corners and CD offsets between isolated and densely packed line CD's.[6]

Optical Proximity Correction (OPC) is a relatively economical method of lithographic resolution enhancement compared to methods like Phase Shift Masking (PSM) etc. It involves the addition of sub resolution features like serifs and scattering/anti-scattering bars to and around the dense and isolated features to enhance the lithographic image on the wafer.

Aerial image plots help explain how line features with the same drawn width can print with different resist CD's . The common assumption is that for any chosen threshold level, an isolated line has a wider aerial image profile than a densely packed one, so the isolated line can be expected to print with a larger CD than the denser one.[1]

In order to CD control, two other OPE issues arise on the mask and gate layers : line end shortening and intersection "pull-back". Both result from the corner rounding effect.[1]

Benefits of OPC include enhancements in DOF , CD uniformity & resolution. An improvement in consistency over exposure and processing conditions. Extending "best-case" resolution to all features and increases contact and via resolution beyond the resolution limit for exposure tool and a reduction in "rounding" or Critical Shape errors (CSE) on Poly lines in logic chips with VLSI+ integration.

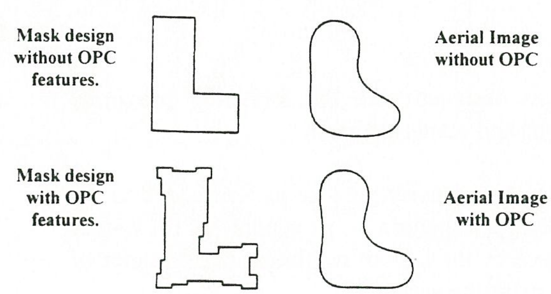


Fig.1 Aerial Image comparison

II. Design Process

In this experiment, a normal binary chrome mask was designed with different lithographic features : lines, spaces, contacts and dense lines/spaces. The features were repeated with varying degrees of proximity correction. The correction feature CD's are varying ratios of λ, the exposure wavelength.

The correction ratios ranged from λ/4 to λ/6. In addition, lithographic simulations were done using Prolith/2 software to determine the minimum Critical Shape Error (CSE) for each of the features with and without the proximity correction.

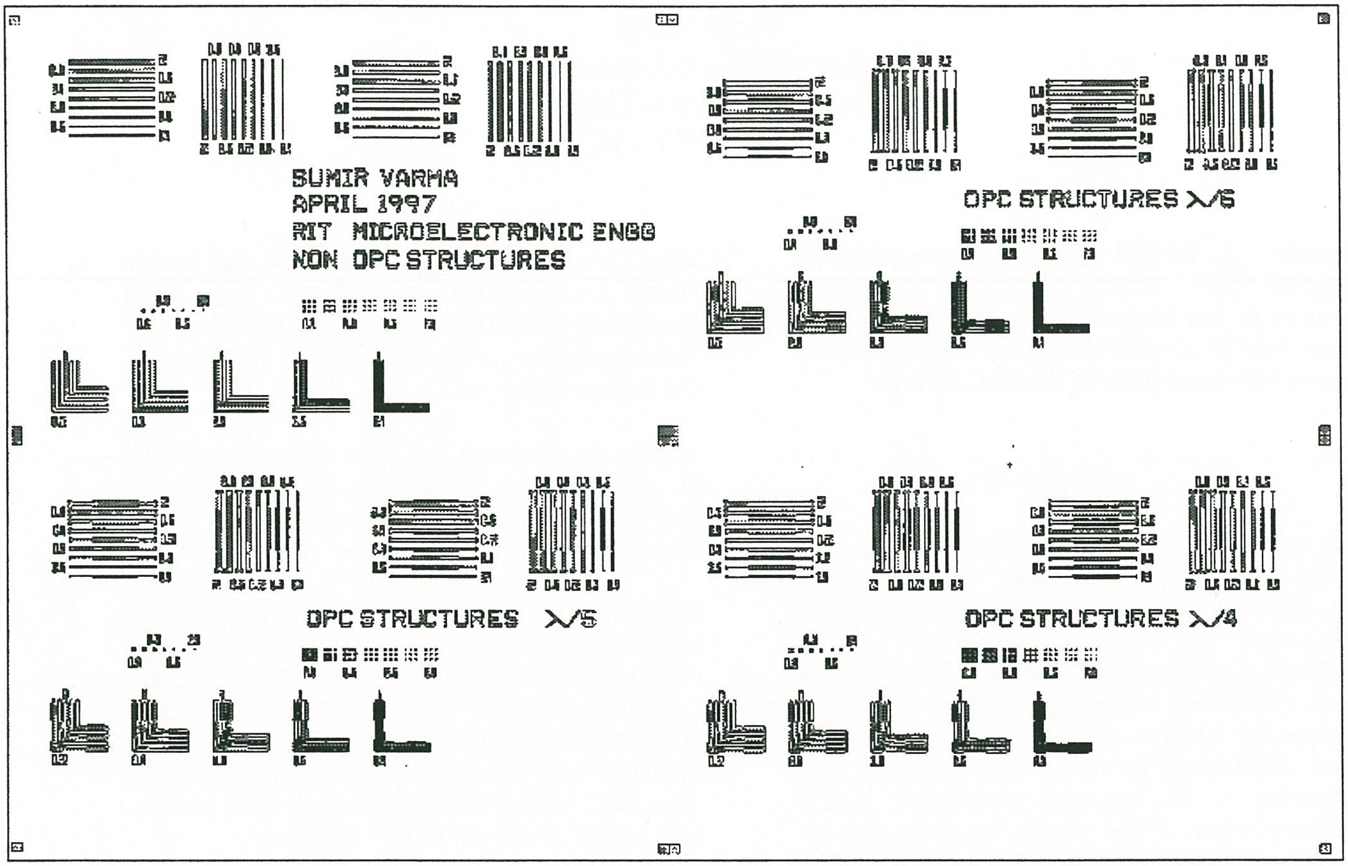


Fig.2 OPC Mask designed for the experiment

The mask was designed with the following proximity features : serifs and scattering bars.

A serif pattern is the unprinting size pattern added to the corner of an original pattern.[2,3,4] It suppresses the corner rounding caused by the lack of resolution performance of a lithography exposure system.

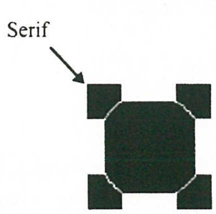


Fig 3. Contact feature with serifs.

Scattering bars are sub-resolution chrome features which are applied mainly to clear field masks.[2,3,4] The purpose of scattering bars is to improve the image intensity level and the aerial image contrast. This is similar to the large DOF that dense lines/space features[5] achieved with Off Axis Illumination (OAI) and it permits the use of these feature for contact feature enhancement. Combining serifs and scattering bars dramatically improves the printability of contact features.

The precise shape of the proximity correction features does not matter, only the size and position are relevant.[5] The ideal placement of the contact feature is offset from the corner, overlapping the main feature by about one thirds of the serif's edge. Similarly, different sized scattering bars can be placed at different distances from the features to create different images.

As shown , different placings of serif features result in different aerial images.

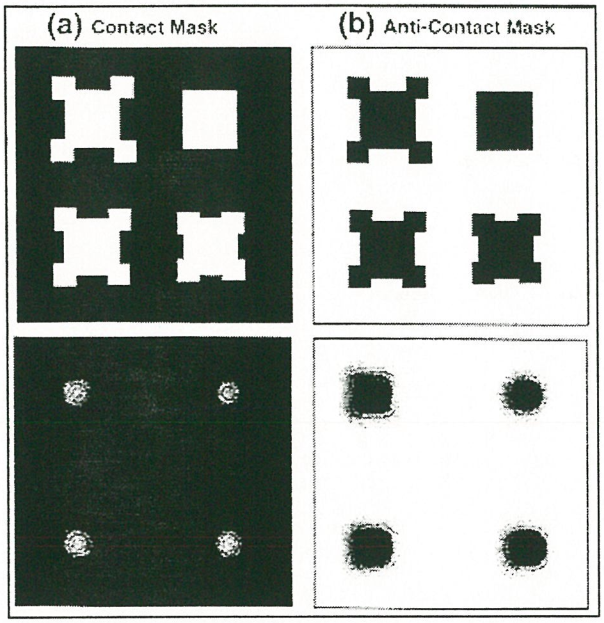


Fig.4 Aerial images due to serif features placed at different positions on contact images.

The mask was written on a MEBES I e-beam system using a spot size of 0.25 μm and a 10 nc beam current with a 10 kV beam. The beam current was not sufficient to write the mask with the scattering bars in place therefore the mask was written without the scattering bars and only the serifs.

The mask was then exposed using a GCA 6700 g-line stepper with a 0.29 NA and a σ of 0.68 onto wafers using positive photoresist.

III. RESULTS

The images showed a distinct improvement after proximity correction features were added.

In the simulation results the features with proximity correction showed a marked enhancement in the aerial image over the non-proximity features. The contacts, lines and elbow features all showed an intensity increase.

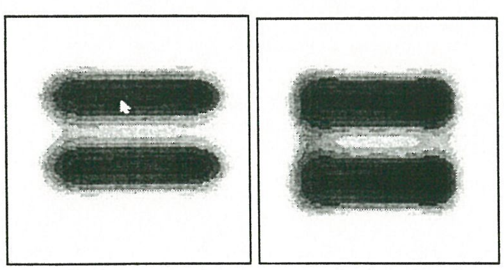


Fig 5. 0.8 μm line without OPC features on left and with OPC features on right.

As seen in the image of a 0.8 μm line above, there is significant rounding at the edges when there are no OPC features. When the OPC features are added, the rounding effect is reduced by a big factor. (Fig.5)

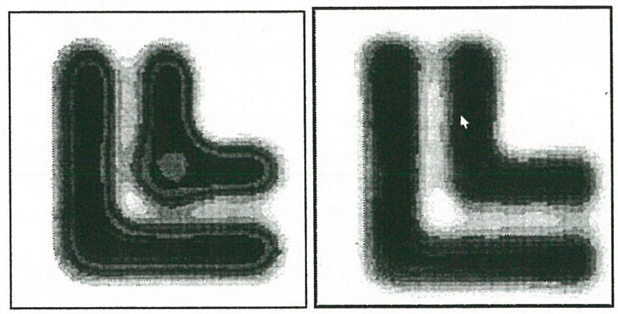


Fig.7 0.8 μm elbow features without OPC (left) and with OPC (right)

Similarly, the image enhancements extended to the contact and elbow features (Fig.7) as well. This was reflected in the Critical Shape Errors as well after running the simulations of Prolith.

Average Critical Shape Error's

	Non-OPC Features		**OPC Features**	
Features	**0.6 μm**	**0.8 μm**	**0.6 μm**	**0.8 μm**
Contacts	73.1 nm	64.6 nm	64.1 nm	55.4 nm
Lines	57.4 nm	52.6 nm	46.1 nm	43.7 nm
Elbows	55.9 nm	48.4 nm	36.2 nm	29.5 nm

Fig.8 Simulation CSE results.

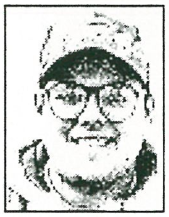
As seen above, the critical shape errors improved for features with OPC. This means less rounding and thinning of the features.

IV. CONCLUSIONS

Drawing conclusions from the experiment, resolution was enhanced for all features : contacts, elbows and lines.
The line shortening and rounding errors were lessened. The addition of OPC features to the elbows resulted in an increase image intensity at the elbow joint. This means that in a poly line, the pattern will develop in the OPC feature, while in the non OPC feature, it wont develop and will essentially be an open circuit.

There was a big decrease in the CSE for each feature which translates into a better and higher definition lithographic image.

The best proximity correction was obtained at a serif size of λ/4 for the contacts and lines. For the elbows, it was a λ/6 serif that resulted in the best image.
For future work, the mask could be designed with a greater variation of OPC features ranging in size from λ/2 to λ/8. This will entail writing the mask on a higher definition e-beam tool. Also OPC effects can be calculated in conjunction with other image enhancement technologies such as OAI and Attenuated PSM.



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Sumir Varma received his B.S in Microelectronic Engineering at Rochester Institute of Technology in 1997. He is a member of IEEE and SPIE and is currently working as a PhotolithographicEngineer with Triquint Semiconductor in Portland, Oregon.

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